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AN INTRODUCTION TO ELECTRONYSTAGMOGRAPHY

By


Ellen T. Benedict

B.A., University of Montana, 1982

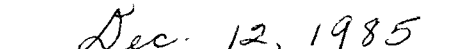
**Submitted to the Department of Communicative Disorders
and the Graduate School of the University of Montana in
partial fulfillment of the requirements for the degree of
Master of Communication Sciences and Disorders**

1985

Approved by


Chairman, Board of Examiners


Dean, Graduate School


Date

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Chapter 1

INTRODUCTION

Electronystagmography (ENG) is a test procedure designed to measure eye movements. The purpose of ENG is to detect and quantitatively measure the eye movements related to specific stimulations of the vestibular system and the oculo-vestibular reflex. A physician can utilize the information obtained through observation of eye movements to determine the anatomic location of a patient's disorder. The ENG recording is a graphic representation of eye movements. Electronystagmographic testing is utilized to delineate peripheral lesions of the vestibular system from lesions located more centrally (Barber & Stockwell, 1980; Hart, 1973).

Electronystagmography is the recording of the corneoretinal potential (CRP). The corneoretinal potential exists due to an electrical field created by the 1 millivolt (mv) difference between the positive potential of the cornea and the negative potential of the retina (Barber & Stockwell, 1980). The electrical field changes as the eyes rotate in the head and is detected by electrodes placed on the skin. The electrical potential is amplified and utilized to drive a writing instrument, which records the movements on paper.

The advantages of electronystagmography are outlined by Rubin (1969) in a paper which supports the use of ENG testing in the diagnosis of the dizzy patient. Rubin pointed out that the test procedure makes it possible to discover nystagmus which is otherwise suppressed with the eyes open. Also, measurement of the velocity of the nystagmus enables the diagnostician to accurately quantify the intensity of the nystagmus. The velocity of eye movement is usually directly correlated to the intensity of the stimulation and the patient's subjective rating of the dizziness (Proctor

& Dix, 1975). A strong stimulation may produce fast eye speeds and a severe subjective rating. The diagnostician can then compare the intensities of nystagmus produced by the various stimuli. With a permanent, objective and repeatable measurement of pathological nystagmus to support the diagnosis, physicians can follow the disease progression. An abnormal electronystagmogram may be the only physical finding to support the patient's complaint (Hart, 1973; Barber & Stockwell, 1980).

ENG results should not be utilized as a specific diagnostic tool and physicians generally do not base a diagnosis on this information alone (Hart, 1973; Barber & Stockwell, 1980). The support of other test results is necessary to make a complete and accurate assessment of the patient's vestibular system as well as the support systems that may be affecting the state of the patient's vestibular system.

NYSTAGMUS

The eye movements evaluated in the ENG are called nystagmus. Barber and Stockwell (1980) define ocular nystagmus as a "to-and-fro oscillation of the eyes". There are different forms of nystagmus which are classified by the type of movement the eyes make. Eye movements in the horizontal plane of approximately equal velocity in each direction are known as pendular nystagmus. During rotational nystagmus, the eyes move in a rotating manner in both the horizontal and vertical planes. The third type of nystagmus, referred to as vestibular nystagmus, contains a slow phase and a fast phase. During the slow phase, the eyes move slowly in one direction; the eyes then jerk back to the center point during the fast phase. The repeated slow-quick jerk movement of the eye in the horizontal plane is characteristic of vestibular nystagmus. Because the goal of this paper is to describe the techniques utilized in the measurement

and analysis of vestibular nystagmus, for the remainder of this paper the term "nystagmus" will be used to refer to vestibular nystagmus.

Nystagmus can be either right beating or left beating. This terminology denotes the direction toward which the fast phase of the eye movement is directed. Right beating nystagmus has the fast phase of eye movement toward the right ear, whereas, for left beating nystagmus the fast phase is toward the left ear (Figure 1).

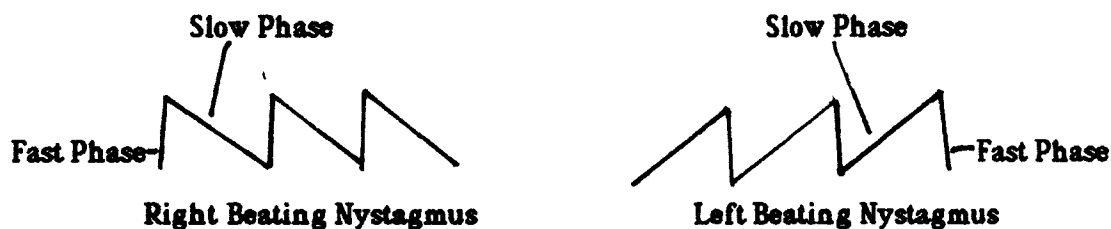


FIGURE 1

The maximum slow component velocity (SCV) of the nystagmus is generally accepted as the most sensitive indicator of the magnitude of the response to stimulation (Barber, 1984, Hart, 1984, Bloem, 1983, and Barber & Stockwell, 1980). There are various methods utilized to obtain the SCV; these include, graphically measuring the slopes, summing the fast phases, and using an electronic velocity computer.

Graphically measuring the slopes requires the selection of several beats from the tracing. In order to obtain a representative sample the beats chosen should include the fastest slow phases of the nystagmus and should not include any artifact (i.e. eye blinks). Through the measurement of eye deviation in a known period of time, the velocity can be calculated. The velocity of the selected nystagmus beats are averaged together to represent the slow component velocity. This procedure can be done manually or with either a plotter or computer. The fast phases can be summed giving the total length of the fast phases over a period of time. This sum

represents total eye movement and is divided by the period of time. Fast phase summing is not very accurate due to the number of artifact that must be included in the measurement.

Velocity computers utilize the peaks in the nystagmus to determine eye speed. The computer is not selective of nystagmus beats and often includes eye blinks and electrical noise in the calculation, which, integrates error into the measurement.

Bloem (1983) reported that the method utilized to compute the slow phase velocity can have a significant impact on the results. Unfortunately, the methods producing the most accurate results are the most expensive and or time consuming.

Chapter 2

STRUCTURE AND FUNCTION OF THE VESTIBULAR SYSTEM

This section of the paper is devoted to a basic description of the structure and function of the vestibular system. The maintenance of body position in space requires information from several systems of the body. The oculo-motor system maintains focus on objects and reveals visual information about where the individual is relative to other objects in space. The muscular system gives information about the amount of gravitational pull being exerted on the body (Baloh & Honrubia, 1982). The vestibular system provides the cerebellum with information regarding head position and movement (Barber & Stockwell, 1980). The information from the eyes, muscles, and vestibular system are integrated to maintain balance in the environment.

The vestibular labyrinth is located in the temporal bone of the skull. The boney labyrinth is filled with perilymph, a fluid surrounding a membranous labyrinth (Barber & Stockwell, 1980). Another fluid, endolymph, fills the membranous labyrinth. The perilymph and endolymph never mix together and maintain an important chemical environment. The sensory cells (also known as hair cells) are imbedded in the walls of the membranous labyrinth in five separate areas (Barber & Stockwell, 1980). The five areas are the lateral semicircular canal, the anterior vertical semicircular canal, the posterior vertical semicircular canal, the macula utriculi and the macula sacculi; they are known collectively as vestibular receptors (see Figure 1). Each area is classified according to the specific stimulus to which it reacts. The semicircular canals respond to angular accelerations of the head, whereas, the saccule and utricle respond to linear accelerations.

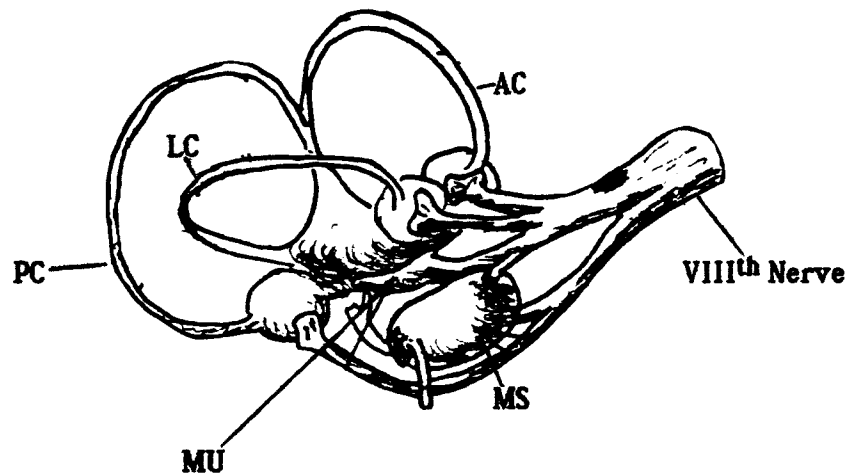


Figure 1

The vestibular receptors, Anterior vertical semicircular canal (AC), Posterior vertical semicircular canal (PC), Lateral horizontal semicircular canal (LC), Maculi sacculi (MS), Maculi utriculi (MU) (Barber & Stockwell, 1980).

The sensory cells contain hairs that project into the endolymphatic compartment of the labyrinth. Hair cells have two characteristics. First, they are constantly excited even in the absence of any external stimulation. Second, the hair cells are directionally polarized, therefore, the hair cells must bend in a specific direction to depolarize the membrane. The consequent depolarization of the membrane causes an increase in the firing rate of the afferent nerve fibers (Barber & Stockwell, 1980).

The hair cells in the semicircular canals are lined up in such a way that they are all polarized in the same direction. The continuous ring of fluid located in the semicircular canals is blocked by a gelatinous plug called the cupula. Fluid movement exerts a force on the cupula which in turn forces hair cells to bend. When the head is at rest, pressure is exerted on both sides of the cupula causing equal force on the hair cells, therefore, no change in the firing of the afferent neurons results.

In total, there are six semicircular canals, three on each side of the human skull. The lateral semicircular canal lies in the horizontal plane. It is the lateral semicircular canal which is stimulated during caloric testing because it is located in closest proximity to the lateral temporal bone, and is therefore, maximally affected by the thermal stimuli (Barber, 1984). Caloric stimulation is a procedure utilized to manipulate the density of the fluid located in the semicircular canals and is described in further detail in the Stimulus Procedure section of this paper.

The otolith organs in the utricle and saccule respond to linear movements. Within the utricle and saccule, the sensory hair cells are embedded in a gelatinous layer and are roughly divided into a medial and lateral section by the striola. The gelatinous layer contains a layer of calcite crystals called otoconia. When a linear movement occurs, the heavier crystals tend to lag behind the moving fluid. The weight of the otoconia is exerted onto the sensory cells and causes the stereocilia of hair cells to bend. The hair cells are polarized in different directions on either side of the striola and it is thought to be the pattern of inhibited and excited sensory cells that codes the information. The hair cells are polarized in the direction of the striola, therefore, an ipsilateral tilt results in an increase in the baseline firing of the units medial to the striola and a decrease in the firing rate of the units lateral to the striola (Baloh & Honrubia, 1982).

Afferent nerve fibers from the five parts of the labyrinth combine to form the vestibular portion of the VIIIth nerve. The vestibular nerve travels out through the internal auditory meatus and go directly to the cerebellum or to synapse with nerves at the vestibular nuclei. The superior, medial, lateral and inferior nuclei are the major vestibular nuclei. The nerve fibers of the vestibular nerve pass through the vestibular ganglion and split at the level of the nuclei to innervate various parts of the body. For example, nerve fibers travel from the superior vestibular nucleus to supply the oculo-

motor system and aid in maintaining visual focus on a target in conjunction with the head position in space. After leaving the spinal and medial vestibular nuclei, some nerve fibers are directed toward the contralateral side of the body while other fibers from the lateral vestibular nuclei travel to the muscles in the body to aid in maintaining body position in space.

Peripheral or Central:

Defining the peripheral vestibular system is a controversial issue in the ENG literature. Unlike conventional audiology, where the VIIIth nerve is considered part of the central nervous system, most people researching and clinically utilizing ENG consider the VIIIth nerve to be a part of the peripheral vestibular system (Barber & Stockwell, 1980; Baloh & Honrubia, 1979). The terminology represents the view point of the neurologist, whereby, neuron tracts outside of the spinal cord and cerebrum are considered to be peripheral. Throughout this paper the peripheral vestibular system will constitute the end organ as well as the vestibular branch of the VIIIth nerve.

Chapter 3

EQUIPMENT AND PATIENT PREPARATION

Equipment

There are basic pieces of equipment necessary in the measurement and stimulation of vestibular nystagmus. It is the availability of ENG equipment that allows physicians to have an objective, repeatable, and permanent record of nystagmus to utilize in diagnosis. The equipment consists of electrodes or PENG goggles, an impedance tester, nystagmograph, fixating points, moving object, optokinetic stripes, water and air caloric irrigators, and an examining table (Kumar, 1981; Barber & Stockwell, 1980).

This section of this paper is devoted to the basic equipment necessary in the measurement and stimulation of nystagmus. The nature of each piece of equipment, as well as how it works, is discussed on a basic level.

Equipment utilized in measurement: Electrodes are the first piece of equipment to be discussed, and various types are available. The electrodes detect the change in voltage produced by the corneoretinal potential and direct the voltage to the input terminals of the nystagmograph. A clean surface is required for a low impedance which in turn reduces the amount of noise in the tracing. A low impedance means that the electrical signal from the skin can be transferred through the electrodes with little resistance, allowing more of the signal to pass through. Barber & Stockwell (1980) recommended electrodes consisting of a pellet surrounded by a plastic cup which are attached to the surface of the skin with electrode paste. More recently, disposable electrodes have been made available which are more convenient to use during set-up and clean-up.

PENG goggles have also been utilized as an alternative to electrodes to detect eye movements (Torok, 1951). The inside rim of one side of the goggles is lined with photosensitive paper which detects a change in light being reflected from the cornea and transforms this signal to an electrical signal. The goggles are placed over the patients eyes and all recording is done with the eyes open. Fixation will not occur because of the darkness created by the closed off goggles. For test procedures requiring visual exercises by the patient, one of the lenses opens up to allow the patient to see the stimulus.

Once eye movement has been detected, either through electrodes or goggles, the signal is carried to the input channel of the nystagmograph. The function of the nystagmograph is to amplify and display the eye movements. There are several parts of the equipment through which the signal is channeled. First, the signal is filtered to obtain a clean response. A clean response should not include electrical noise or muscle artifact. The amount of filtering is determined by the operator to maximize the quality of the tracing. The signal then travels through a preamplifier which boosts the voltage of the input signal. The electrical field created by the corneoretinal potential is too weak to drive a pen along the tracing and requires amplification. After the signal has been increased, a power amplifier converts the voltage to an electric current which, in turn, drives the output transducer. Within the output transducer, a galvanometer utilizes the incoming electric current to make a corresponding move in pen position. A paper drive moves the paper under the pen creating a tracing which displays eye movement over a period of time.

Equipment utilized for stimulation: Various pieces of equipment are utilized to elicit nystagmus. Much of the equipment design solves two problem for the operator. First, the equipment offers the operator increased control of the stimuli, and second, it provides convenience during test administration.

Calibration, saccade testing and gaze testing require a series of points upon which the patient must fixate (Barber & Stockwell, 1980; Troost, ENG Report). Dots or lights on the wall or ceiling should be placed at 10°, 20°, and 30° visual angle along a horizontal line from each other. Light bars are often used in clinics because the lights are easy for the patient to see as well as convenient for the examiner to operate.

A moving object is utilized to test the pursuit system. The target should move through a field of approximately 30° visual angle with a peak velocity of 40° per second. Barber and Stockwell (1980) suggest a swinging tennis ball, but something like a metronome is easier to control for speed.

Optokinetic stripes can be presented in various ways. A motor driven rotating drum with stripes painted on it is often utilized. A cylinder with the stripes painted on the inside was designed to surround the patient's head. The cylinder offers more control of the stimulation because it incorporates a large portion of the patient's visual field, but is more cumbersome to have in the laboratory. Also utilized is a projector showing the stripes passing on either a screen or the wall of the examination room.

Caloric testing can be a very cumbersome task without the use of adequate equipment. A unit utilized to deliver the water during the calorics portion of the test should contain two reservoirs to hold water at the proper temperatures. A delivery system to move the water to the ear, as well as a timer, are also necessary. If air is the stimulus of choice, a unit which forces the air through a thermoelectric device, which either cools or warms the air, is often used. The machine must also deliver the air to the irrigating tip and contain a timer as well.

The above mentioned equipment is considered basic to the ENG laboratory. With recent developments in technology, the field of ENG testing will become more and more complicated, offering increasingly more information about the vestibular system and possible lesions. Computer technology is already making the

analysis of the nystagmus as easy as pressing two buttons to obtain a slow component velocity. Computers are also being utilized to present the stimuli, thereby offering a great deal more control over the stimulus (Honrubia, Jenkins, Baloh, & Lau, 1982; Bloem, 1983). With greater control of the stimulus, more specific information regarding the vestibular system can be obtained.

Patient preparation:

There are pre-test procedures which must be completed as much as 48 hours prior to test administration. To ensure accurate and reliable results during the test procedure the patient must be adequately prepared.

First, the patient must not be allowed to take any drugs such as sedatives, antihistamines or anti-dizziness medications, nor should the patient have consumed any alcohol or caffeine for as much as 48 hours prior to testing. These medications have been shown to affect the nystagmus elicited by various stimuli (Barber & Stockwell, 1980; Dayal, Farkashidy, Tarantino, & Thibert, 1977). If the patient has had any of these substances, test results cannot be considered to be an accurate account of the functioning of the vestibular system. The patient should not be tested until the examiner is certain that no other factors are entering into the responses obtained during the testing.

The patient should also be instructed not to have eaten prior to testing. Because nausea often accompanies dizziness, this rule is for the protection of both the patient and the examiner. The patient will experience less discomfort and the testing can run smoother with less interruptions.

Electrode placement is the next necessary step in the preparation of the patient. The surface of the skin should be cleaned to remove any dead skin cells which can increase the impedance between the electrodes and the skin. As was previously stated,

three electrodes are utilized to detect the electrical field of the corneoretinal potential (CRP). When measuring the eye movements in the horizontal plane, two electrodes are placed laterally from each eye and are the active electrodes (electrodes that pick-up the electrical activity). The third electrode is the ground electrode and can be placed anywhere on the body away from the eyes; the forehead is most often used. According to Snyder and Stockwell (1985), maximal placement for the active electrodes is approximately 10 mm from the eye and no more than 25 mm away. The researchers found that when the electrodes are placed too far away from the eye, an increased gain is necessary to pick up the electrical potential. Electrodes placed close to the eye will result in less noise interference in the tracing. When the electrodes are placed close to the eye, the electrical signal will be stronger and will require less gain on the amplifier.

The eye movements should be calibrated with the movement of the pen on the nystagmograph. This portion of the test is also utilized in the examination of the saccade system, and is discussed in further detail under the stimulus procedure section. For calibration, the patient is required to look back and forth between visual targets separated by 10° and 20° visual angle in the horizontal plane. The gain of the nystagmograph is adjusted to obtain a peak-to-peak pen deflection of 10 mm and 20 mm, respectively. Snyder and Stockwell (1985) suggested that calibration be repeated throughout the test sequence due to the possible affects illumination may have on the corneoretinal potential. An increase or decrease in the illumination in the room will cause subsequent changes in the CRP and can have an affect on the strength of the electrical signal being picked-up. For example, if the light is turned on during the testing, the corneoretinal potential will be increased and will indicate an increase in the distance of the eye movement.

Once the above mentioned steps have been taken, the patient will be ready to begin the evaluation. The evaluation consists of several stimulations designed to induce nystagmus under controlled conditions. The stimulations and the clinical significance of the results will be discussed in the following chapter.

Chapter 4

STIMULUS PROCEDURES AND CLINICAL SIGNIFICANCE

The next section of this paper will define and describe the stimuli utilized during Electronystagmographic testing. The localizing value of the results as they are reported in the literature will also be discussed.

There are no standards that dictate the procedures for measurement, stimulation or analysis of the the electronystogram. Each examiner must determine the specific procedure that will reveal the results that are most useful to him. The amount of time the test takes as well as patient comfort are important considerations in this matter.

Various stimuli have been introduced in the literature to elicit nystagmus (Barber & Stockwell, 1980; Barber, 1984; Torok, 1951, Brookler, 1975). Eliciting the nystagmus allows the physician to measure and analyze eye movements. Some stimuli are designed to create normal vestibular situations in an attempt to learn how the system reacts under normal circumstances. Other stimuli create an imbalance in the vestibular system to measure how the system reacts to the imbalance.

Spontaneous, positional, positioning, gaze, saccade, optokinetic, rotatory and caloric stimuli are most commonly utilized. Each of the above procedures and the respective results obtained will be discussed in the following pages.

Spontaneous Nystagmus

Spontaneous nystagmus is nystagmus that is present while the patient is in a neutral position (i.e., sitting) when no external stimulation has been applied (Barber & Stockwell, 1980; McClure, 1983; Dayal, Tarantino, Farkashidy, & Paradisgarten, 1975).

Whatever the stimulus that is to be used during the examination, a measurement of both spontaneous and positional nystagmus must be made (McNally, 1969). The presence of either type of nystagmus is not only pathological, but may also confound the results obtained during other stimulus presentations. For example, a patient that has 12° of spontaneous right beating nystagmus can show a unilateral weakness during caloric testing if the spontaneous nystagmus is not accounted for in the calculation of the sensitivity difference and the directional preponderance.

Procedure: A measurement of spontaneous nystagmus is obtained while the patient is sitting upright and facing forward. A tracing of eye movement is made with the eyes open and fixated as well as with the eyes closed for approximately 30 seconds (Barber & Stockwell, 1980; Baloh & Honrubia, 1979). Fixation is the ability of the patient to maintain visual focus on an object and can often result in the suppression of the nystagmus.

Clinical significance: The presence of spontaneous nystagmus indicates an imbalance in the vestibulo-ocular pathways which can be due to either central or peripheral lesions (Baloh & Honrubia, 1979). Certain characteristics of the nystagmus will aid in identifying the site of lesion. For example, spontaneous nystagmus that is due to lesions of the labyrinth or VIIIth nerve will be inhibited by fixation (Baloh, ENG Report: Central Electronystagmographic Signs). Baloh also states that the nystagmus will be rotatory because of the combined effects of altered vertical and horizontal semicircular canal input. Another localizing finding that is indicative of a peripheral lesion is known as Alexander's Law. In the case of Alexander's Law, gaze in the direction of the fast component of the spontaneous nystagmus will increase the frequency and amplitude of the nystagmus while the opposite response will occur with gaze in the direction of the slow component (Barber 1984).

Spontaneous nystagmus due to central pathology will be in either a horizontal or vertical direction and will not display the rotatory component, because the central pathways of horizontal and vertical motor neurons separate at the vestibular nuclei and run their individual courses to the brain. There is little chance that both pathways would have lesions. Another localizing sign indicating central pathology is that the nystagmus will not be inhibited by fixation; the intensity of the nystagmus will be the same with the eyes open as it is with the eyes closed.

Positional Versus Positioning

This section of this paper is dedicated to the delineation of the terms "Positional" and "Positioning" testing. Positional refers to the nystagmus present when the head is in a given position and is caused by the head position alone. Positioning testing, on the other hand, refers to the nystagmus present because the head is moved into a position and is caused by the movement and not by the head position itself. Positioning nystagmus is also known as paroxysmal nystagmus. The two stimulations affect different systems and will be discussed separately.

Positional Nystagmus

"Positional nystagmus" is defined as nystagmus that is present only when the head is placed in a certain position or when the nystagmus is influenced by the position of the head (Barber, 1984; McNally, 1969). The positions most commonly utilized to stimulate nystagmus are supine (0° & 30°), right and left neck torsion, right and left lateral, and head hanging in the center as well as to the right and to the left (Barber, 1973; McNally, 1969; and McClure & Lycett, 1983).

Procedure: More specifically, the supine position requires that the patient lie down with the head at 0° (parallel with the ground) and then tilted up 30° from horizontal. The recording is made for approximately 30 seconds in each of the positions with the eyes closed. While the head is tilted up 30° , the horizontal semicircular canals will be in the vertical plane which maximizes the effects of gravity on the endolymphatic fluid. The patient turns on to his/her right or left side for the lateral positions while the presence of nystagmus is observed and recorded. Recording in the right and left neck tortions position requires that the patient remain lying on his back with his head turned to one side, holding it in that position while the examiner records eye movements for 30 seconds.

The tracings are examined for the presence of nystagmus in any of the positions. If nystagmus is present, the slow phase velocity is measured to determine the eye speed. The direction of the eye movements is compared between the various positions.

Positional nystagmus is classified by the different forms that may be elicited. Aschen (1939) utilized duration and direction of the eye movement to classify the various types of positional nystagmus he noted. According to Aschen, Type I positional nystagmus is persistent as well as direction changing, type II is persistent and direction fixed and type III is transitory in nature. "Persistent" means that the nystagmus last for at least one minute after assuming a given position. "Transitory" nystagmus goes away within one minute. The direction of eye movement refers to the nystagmus beating in one direction regardless of the change in position of the head and is known as "direction fixed". The type of nystagmus that changes direction with a corresponding change in head position is "direction changing".

Clinical Significance: Positional nystagmus does not occur in normal humans when the eyes are open and fixated (Barber, 1984). On the other hand, approximately

20% of normals with eyes closed and mental alerting will demonstrate both direction changing and fixed nonparoxysmal with a slow component velocity of 7° per second or less. Visual fixation will suppress any positional nystagmus that may be present (Barber, 1984; McClure, 1983). Positional nystagmus found when the eyes are open and fixated is always pathologic (Barber, 1984). Although the head is in the same position for both the lateral and neck torsion tests, the two positions should always be recorded, especially if nystagmus is present during the lateral position. While the neck is turned in the neck torsion position, the blood flow to the brain can be restricted and may be the cause for the dizziness. One way to determine if the lack of blood flow is the cause is to observe the nystagmus in both positions. If the nystagmus is present in both positions, then the access of blood to the brain is not affecting the nystagmus.

Nylen (1939) as cited by Baloh and Honrubia (1982), introduced the term "positional nystagmus" and differentiated between direction fixed and direction changing, stating they are peripheral and central localizing signs respectively. Dayal, Tarantino, Farkashidy and Paradisgarten (1975) assessed the nystagmus of 302 patients with spontaneous, positional or paroxysmal (positioning) nystagmus and found that none of the above classifications have any localizing value and all three types of nystagmus can be found in cases with peripheral as well as those with central lesions.

McClure (1983) states the confusion over direction fixed versus direction changing is due to the definitions of spontaneous and positional nystagmus. He suggests Barber and Stockwell confuse the issue by insinuating that spontaneous and positional nystagmus cannot co-exist. McClure's explanation of direction changing versus direction fixed nystagmus is that the ever-present spontaneous nystagmus influences the strength of the positional response in either direction. For example, when the spontaneous nystagmus is present it will add to the strength of the positional response in the same direction where as, in the opposite direction, the spontaneous

nystagmus will subtract from the positional response. If the spontaneous nystagmus is stronger, the result will be direction changing nystagmus.

Positioning Nystagmus

As previously stated, positioning nystagmus is the movement of the head into a given position that elicits positioning nystagmus. This type of nystagmus is the most common, therefore, this test should be performed on every patient who is physically capable (Barber & Stockwell, 1980).

Procedure: The procedure utilized to elicit this nystagmus is known as the Hallpike maneuver (Barber & Stockwell, 1980; Slater, ENG Report). During this test the patient is moved rapidly from sitting upright back to the supine position where the head is hanging off the table and turned to the left. The patient should hold that position for approximately 30 seconds. The patient is then moved back to the sitting position and the maneuver is repeated, but this time the head is turned to the right. During the head hanging position the patient is lying down on the table with the head hanging off at approximately a 45° angle. Recording takes place throughout the movement procedure. The recordings should be marked and sectioned for each movement. The procedure should be repeated to determine if the nystagmus is less intense and diminishes with repeated stimulations. Patient's with severe back injuries should not undergo this test and special care should be taken with elderly patients.

Clinical significance: The tracings are inspected for the presence of nystagmus during any part of the test. There are characteristics of the nystagmus that set it apart from positional nystagmus. A 3-10 second latency should occur between the completion of the movement and the start of the nystagmus. The nystagmus should also only last for a 15 second duration and not for the whole 30 seconds that the recording is done.

Upon repeated stimulations the intensity should fatigue and eventually be absent (Barber & Stockwell, 1980; Slater, ENG Report). And lastly, the nystagmus should beat toward the uppermost ear.

Positioning nystagmus that displays these classical patterns is indicative of a peripheral lesion. "Benign Paroxysmal Vertigo" is utilized to describe the disease process that is responsible for the nystagmus. The most accepted explanation for this disease is that loose otoconia fall back and stimulate the semicircular canals when the patient is moved so rapidly.

Saccades

A saccade is an eye movement that maintains the portion of the retina that focuses on the target from one intentional point to the next. The ocular motor system allows the eyes to move fast from one point to the next and to fixate on the intended target with the fovea of the eye (Troost, ENG Report:). The fovea of the eye lies along the retina and is the only portion of the retina able to maintain the fine focusing on an object.

The saccade portion of the ENG serves two purposes. First, the movements the patient is asked to perform are utilized to calibrate the equipment and second, to detect any disorders of saccadic eye movement.

Procedure: The patient is asked to follow the lights on the ceiling or wall while maintaining the same head position and only moving his eyes. The lights are at 10° and 20° visual angle in each direction from central gaze position along a horizontal plane.

Clinical significance: The tracings are inspected for several abnormalities such as calibration overshoot and undershoot. Overshoot occurs when the patient is unable to follow the target directly and will move his eyes too far and have to move

them back to focus directly on the target. Undershoot occurs when the patient's eyes fall short of the target and he then makes compensatory movements to the target. Barber and Stockwell (1980) state this finding is only pathologic if the tracings show a clear cut overshoot or undershoot abnormality. The authors also stated unidirectional overshoot is more common than overshoot that occurs in both directions. A lesion of the cerebellum could result in both overshoot and undershoot abnormalities (Baloh, ENG Report:Central ENG Signs).

Saccade slowing is another abnormality the tracings are inspected for. A normal eye will move to a target that is 20° at 188°/second. A disease process such as Supranuclear palsey or Parkinson's will slow the eye movement. An abnormal tracing of the saccades is a central localizing sign whether it be saccade slowing or overshoot/undershoot.

Superimposed gaze nystagmus and congenital nystagmus can interfere with the results and produce an abnormal saccade (Barber & Stockwell, 1980). Drugs can also affect the saccadic eye movement system and is most commonly observed in ocular dysmetria (each eye moves at seperate speeds or distances). Before tracings of saccadic eye movement can be labled abnormal, the above problems must be ruled out as the cause for the abnormalities.

Gaze Nystagmus

Barber & Stockwell (1980) state the primary purpose of the gaze test is to detect nystagmus while the head remains still and the eyes are systematically directed at center gaze and then deviated both horizontally and vertically from the center position.

Procedure: The patient is asked to look straight ahead and then, without moving his head look 20° to the right hold his eyes in that position and then 20° to the left. The test is repeated at 30° from center gaze. Recording with the eyes in at 20° and 30° , eyes open is for 15 seconds. Many authors recommend the gaze test be completed with the eyes closed (Baloh, ENG Report; Barber & Stockwell, 1980). Although the information that is obtained may be valuable there is no way for the examiner to be certain that the patient has been able to maintain that eye position. The ability to hold the eyes in any position other than center gaze with the eyes closed is very difficult. The examiner should be very careful making any diagnosis based on results obtained with the eyes closed.

Clinical significance: Gaze invoked nystagmus indicates a central nervous system dysfunction (Baloh, ENG Report: Central ENG Signs). Barber & Stockwell (1980) report gaze invoked nystagmus due to central pathology will be enhanced with fixation and reduced when the eyes are closed. The authors also state a peripheral lesion will demonstrate the opposite phenomenon, nystagmus is enhanced by eye closure. According to Baloh, the only time that a peripheral vestibular lesion would result in gaze nystagmus is during recovery from a lesion for a transient period of time and only on gaze in the direction of the fast component. The most common cause of gaze-evoked nystagmus is sedating drugs (Baloh, ENG Report: Central ENG Signs). Asymmetrical nystagmus, also known as Bruns' nystagmus indicates a structural brainstem or cerebellar lesion, with the lesion on the side with the larger amplitude nystagmus.

Tracking, Smooth Pursuit

The pursuit system enables the patient to maintain contact between the fovea portion of the retina and a moving object while the head remains in a stable position (Stockwell, ENG Report: Testing Of The Pursuit System). Pendular tracking tests are designed to tax the smooth pursuit system and to evoke any abnormal eye movements that may otherwise go undetected.

Procedure: The patient is asked to follow a moving object in the horizontal plane (i.e. a tennis ball hanging from the ceiling and swinging in a pendular fashion, a metronome, or a finger). The patient must only use his eyes to follow the object while keeping his head in one position. The total excursion should be about 30° from center gaze and moving at about 40° to 50° per second (Barber & Stockwell, 1980).

Clinical significance: The tracing is inspected for smooth eye movements while following the object. Cogwheeling occurs when saccadic movements are substituted for smooth eye movements (Barber & Stockwell, 1980). The eyes are unable to keep up with the target and will make compensatory jerk movements to catch up with the object. This type of abnormality is thought to be due to a brainstem lesion involving the pursuit system (Barber & Stockwell, 1980).

Drugs, a noisy record, inattentive patient, head movement, and superimposed gaze and congenital nystagmus can interfere with the tracing and should be ruled out as a possible cause.

Optokinetic Nystagmus

Optokinetic nystagmus is a combination the pursuit and saccade systems. The stimulus is utilized to evaluate the function of the visual-oculomotor reflex pathways. A

precise relationship exists between the speed of the optokinetic stimulus and the resultant nystagmus, particularly the SCV (Jenkins, Honrubia, Baloh, Yee, & Lau, 1979).

Procedure: The optokinetic stimuli most often used are stripes that move across the wall or spin on a drum at varying speeds of 10°, 20°, 40°, 60°, and 80° visual angle per second (Barber & Stockwell, 1980). The patient watches the stripes move to the right and then to the left. The patient is instructed to notice each stripe and not to follow any stripe.

The slow phase component of the induced nystagmus should be symmetrical in each direction and should equal the speed of the stimulus.

Clinical significance: Assymetry between the recordings is a central nervous system sign. A difference between each direction of 30° degrees is considered to be a significant abnormal finding (Barber & Stockwell, 1980). Left and right beating may be symmetrical but may be low intensity and is also considered to be pathological

Drugs and an inattentive patient can interfere with the recording (Barber & Stockwell, 1980).

Rotatory Testing

Although Rotational testing is not a standard procedure in the ENG protocol utilized in a large majority of clinics, the procedure does deserve some mention. The procedure is designed to produce angular rotations of the body while ENG equipment measures the consequent eye movements.

During this procedure a motorized chair rotates on a vertical axis with the head in a fixed position causing angular rotation in the plane of one of the semicircular canal pairs (Baloh, Yee, Jenkins, & Honrubia, 1982; McNally, 1969). Various forms of rotation have been analyzed including, sinusoidal, trapezoidal, harmonic and

psuedorandom (Wall & Black, 1983; Baloh, et. al., 1982; McNally, 1969; and Wolfe, Engelken & Olsen, 1982).

Baloh, et. al. (1982) state with the computerized technology available, the examiner is able to present multiply graded stimuli and obtain accurate representations of eye movements in a relatively short period of time. The authors also state rotational testing is less bothersome to patients than calorics. More and more research is being done on this procedure in an attempt to refine the procedure to obtain a maximal amount of information about the vestibular system as well as the support systems.

At this point in time, there is not enough information available to justify having such expensive and combersome equipment in a clinic. McNally (1969) states this test is better suited in a laboratory. Eventually, with the development of even more sophisticated test procedures, this procedure may well become an integral part of an ENG laboratory in a clinic.

Thermal Stimulation

Thermal stimulation, also known as caloric stimulation, is the manipulation of the relative temperatures of each labyrinth which causes the endolymph to react in a predictable manner. This section is devoted to the theory and techniques utilized in the manipulation of the temperature of the labyrinths.

Caloric testing allows the examiner to stimulate and examine each ear separately. Abnormalities noted during caloric testing are often the only significant findings in Electronystagmographic testing (Hart, 1984). Hart (1984) considers caloric stimulation to be the "most useful vestibular test by far" (Page 1) and Barber & Stockwell (1980) state that although the test is the most time consuming it is the "most important test in the ENG examination" (Page 159).

Caloric stimulation produces nystagmus by activating and inhibiting the firing of vestibular afferent nerves. The principle mechanism involved is convection of the endolymph in the semi-circular canals (Stockwell, ENG Report). The strongest stimulation occurs when the patient is situated so that the horizontal semicircular canals are in the vertical plane (Stockwell, ENG Report; Baloh & Honrubia, 1982). With a warm stimulus, the heat first reaches the most lateral part of the horizontal canal and warms the endolymph. Warm endolymph will rise, and put pressure on the lateral side of the cupula causing it to bend medially. This reaction causes an asymmetry between the firing rates occurring in the left labyrinth versus the right labyrinth. This type of stimulation causes the sensation of rotating the head to the side of stimulation and produces an eye movement that deviates away from the stimulated side which is interrupted by saccades, or jerks of the eye, toward the side stimulated.

A cold stimulus causes the opposite reaction because the cooling of the endolymph causes the fluid to fall rather than rise and bends the hair cells in the opposite direction. Because bending the hair cells one way is excitatory and in the other direction is inhibitory, the falling endolymph actually inhibits the firing of the nerves causing an asymmetry in firing rates between vestibular systems. With a cold stimulus, the sensation of rotation will be toward the opposite side of the stimulation. The difference in the normal response between cold and warm is affectionately termed "COWS", which stands for "Cold-Opposite, Warm-Same".

The temperature of the stimulation has a direct effect on the firing rate of the nerves themselves in addition to that caused by the convecting endolymph. A warm stimulus increases the firing rate and a cold stimulus decreases the rate. This phenomenon can actually effect the results of the caloric by as much as 20% (Coats & Smith, 1967).

The caloric test is specifically testing the horizontal semicircular canals. Because the vertical canals are so deeply imbedded in the temporal bone stimulation does not work well in practice. Measurement of the eye movements from the vertical canals are difficult to measure because they are vertical-rotary.

The thermal stimulations have been applied in different forms, temperatures, durations, and stimulus patterns. Water and air are the most popular types of stimuli utilized to adjust the relative temperatures of the labyrinth. Ice water at 0° is the coldest stimulation and is considered to be the most drastic stimulus (Stockwell ENG Report; Baloh & Honrubia, 1982). Both cold and warm stimulations have been applied, some at the same time as well as separately in various procedures. (Barber & Stockwell, 1980; Brookler, 1975). Some examiners use only one temperature to determine the sensitivity of the vestibular system (Torok, 1951). The Bithermal Caloric Test, Monothermal Caloric Test and the Simultaneous Binaural Bithermal Caloric Test are three procedures that will be discussed in this section. Each test will be addressed in terms of the procedure, theory, and the localizing value.

Bithermal Binaural Caloric Test

The first procedure of caloric stimulation to be discussed is the most widely used (Barber & Stockwell, 1980). The procedure is known as the bithermal caloric test.

Procedure: The procedure requires the patient lie down in a supine position with the head tilted up at a 30° degree angle (Baloh & Honrubia, 1982; Barber & Stockwell, 1980). When the head is elevated 30° from supine, the horizontal semicircular canals are placed in the vertical plane. The best way to ensure the head is in the correct position is to imagine a line that goes from the lateral corner of the eye

to the ear then, check to see that this line is perpendicular to the table or floor. This line is known as "Frankfurt's Line" (Barber & Stockwell, 1980). Stimulation of the semi-circular canals is through irrigation of the external auditory canal with water or air either above or below the relative body temperature. The temperature gradient created through stimulation is then transferred to the inner ear via conduction (Baloh & Honrubia, 1982).

The temperature of the stimulus and the duration of the irrigation period are determined by the type of stimulus utilized. Air, water and ice water are three stimuli commonly used to manipulate the temperature of the semi-circular canals. Water stimulation is at 7° above (44°C) and below (30°C) body temperature at a constant flow for 30 seconds. When air is the stimulus of choice the temperatures are 24°C and 50°C for cold and warm respectively for a duration of 60 seconds. The patient receives four stimulation sets, 2 stimulations in each ear. The first stimulus is with cold air or water in one ear and then in the other ear. The third and fourth stimulations are with the warm air or water in each ear. Because the effects of the stimulation can last as long as 8 minutes, a 5-10 minute rest period is given inbetween each stimulation to prevent the previous stimulation from effecting the present one.

Capps, Preciado, Paparella and Hoppe (1973) studied the responses obtained utilizing water versus air as the stimulus and compared the results. The authors found air at 0°C versus 5cc of ice water produced the same amplitude and eye speed of responses. The only difference was found in the duration of the response produced with the ice water, which lasted longer than the response produced with the air. When they compared the difference in responses obtained utilizing water at 30°C and 44°C for 30 seconds and air at 24°C and 50°C for 60 seconds they determined no significant difference in the responses obtained with cool. For responses obtained with the warm stimulation, the eye speed was equal but the response lasted longer with the water.

Once again, the major difference occurred when water was used, the duration of the response period was longer. The authors concluded air was the stimulus by choice because of the convenience, patient tolerance, wider applicability (patient's with perforations of the tympanic membrane can be tested with air and not with water) and because it is much less aversive and more pleasant for the patient.

Ice water stimulation is the most severe stimulus and will induce the the strongest response. Generally, ice water is used as a gross measure of vestibular function in the physician's office or when no response has been obtained with air and water stimulation (Baloh & Honrubia, 1982).

Recording of the response begins at the end of the irrigation period with the patient's eye closed. During the recording, the patient must remain alert and perform a mental task that will take the his mind off the dizziness and prevent suppression of the response (Barber, 1973). This is done because the ability to suppress the effects of the stimulation can be very strong. Often times the patient is asked to count backwards from 100 or to name streets, or boys names to keep him alert and to prevent suppression from occurring.

Just after the nystagmus has reached its maximum response level, the patient is asked to open his eyes and to fixate upon a point or light at central gaze position. Recording of the nystagmus is continued throughout this procedure.

Clinical significance: The tracings are examined for response strength and compared between both ears and temperatures. The slow component velocity (SCV) is measured and represents the strength of the response (Proctor & Dix, 1975). The slow component velocity is a measurement of how fast the eye moves around in the socket.

The following is a formula designed to determine the sensitivity difference between the SCV of both ears:

$$\text{SENSITIVITY DIFFERENCE} = \frac{(RC+RW) - (LC+LW)}{(RC + RW + LC + LW)} \times 100$$

Where RC-right cold, RW-right warm, LC-left cold, and LW-left warm. A difference of 20% or more is a significant finding and indicates a unilateral weakness on the side with a lower SCV (Barber & Stockwell, 1980). A unilateral weakness as the only abnormality indicates a peripheral lesion, probably located in the labyrinth, but possibly along the VIII nerve.

The ENG tracings are also examined for a "Directional Preponderance". The following is the formula utilized to determine the directional preponderance:

$$\text{DIRECTIONAL PREPONDERANCE} = \frac{(RC+LW) - (LC+RW)}{(RC+RW+LC+LW)} \times 100$$

Where RC-right cold, RW-right warm, LC-left cold, and LW-left warm. A significant directional preponderance has occurred when the direction of the caloric nystagmus is 30% or more stronger in one direction than the other (Barber & Stockwell, 1980). Eviater & Wassertheil (1971) determined in a study of 1,101 patients that directional preponderance is significantly connected to central nervous system lesions but that the association is too small to be a specific diagnostic sign. An interesting point is that Stockwell (ENG Report) found this abnormality is almost always accompanied by spontaneous nystagmus in the direction of the preponderance. Directional preponderance is considered to be a non-localizing sign and when is the only abnormal finding in the complete ENG evaluation is more likely to be due to tester error.

A comparison of the nystagmus present while the eyes are closed versus the nystagmus present with the eyes open gives the physician important information regarding the patient's ability to suppress the nystagmus. Nystagmus present when the eyes are open and fixated is pathological and is an indicator of central pathology (Barber, 1984; Hart, 1984).

This procedure is sensitive to unilateral lesions, but is relatively insensitive to bilateral lesions (Stockwell, ENG Report Rationale for bithermal Caloric Test). For a bilateral lesion there will be two weak responses and will need a very weak response for it to fall below normal limits. In order for a response to be considered weak, it must be less than 7°/sec. Bilateral hyperactive labyrinths may also be missed because there will not be a sensitivity difference. A response that has a SCV greater than 50°/sec is significant and is representative of a hyperactive vestibular system (Barber & Stockwell, 1980).

The major problems with this type of stimulation is the amount of stimulation the patient actually receives can vary. The stimuli are in a sense uncalibrated. The examiner must be certain the flow of air or water is directed toward the tympanic membrane to ensure the maximum amount of stimulation reaches the bony labyrinth. For some patients, the ability to direct the air flow around some of the corners of the external auditory canal can be very difficult. Another complaint of this stimulation is responses from individual to individual are highly variable.

Monothermal

Monothermal testing described by Torok (1951) requires four stimulations, two on each ear. Like the bithermal method discussed previously, the change in the temperature of the endolymph will cause the fluid to either rise or fall. This test

utilizes only one temperature, 20°C, for all stimulations. The difference between the stimulations on a given ear is the duration of the stimulation and the intensity of the flow of the water.

Procedure: The first stimulation requires 10ml to be delivered over a five second period. This is considered to be the weaker stimulation. During the time the water is delivered to the ear, the patient's head is flexed down 30°. At the end of one minute (measured from the onset of stimulation) the head is moved back to 90°. During the time the head is at 30°, no convection currents will be started up because the lateral canals are in a truly horizontal plane. Once the head is moved back to 90°, and the lateral canals are brought into the vertical plane the convection currents will begin. Recording of the response begins when the head is in the 90° position and the convection currents have begun. The second set of stimulations, the strong set, require 100ml over a 20 second stimulation period. The patient's head is 60° from upright during both the stimulation and the recording. Upon completion of the stimulation, the recording should begin. Both a weak and a strong stimulation should be obtained from each side of the head.

Clinical significance: Analysis of the nystagmus created during the stimulations requires calculating what is called the "culmination frequency". The two consecutive five second periods which the maximum number of beats is reached during the tracing is called the culmination frequency and represents the sensitivity of the horizontal semicircular canal. A normal response for the weak stimulation should be between 3-29 beats and for the strong between 10-39 beats. The examiner then must calculate the ratio between the obtained values for the weak and the strong on each side. The ratio can be determined by taking the culmination frequency of the strong

stimulation and dividing it by the culmination frequency of the weak stimulation. The normal range for the ratio between stimulation is 1.2-3.5 (Torok, 1951).

Kumar (1981) describes seven possible test results. Normal symmetric responses, asymmetric response with a difference between the two sides greater than or equal to 25%. Hypoactive responses for which the culmination frequency are below the values for normal in both the weak and strong measurement phases versus the hyperactive response when the responses are both greater than the normal range during both stimulations. Hyperactive responses indicate a defect of inhibition in the vestibulo-ocular reflex arc (Kumar, 1981). Areflexia occurs when the maximum stimulation fails to induce any nystagmus and indicates a non-functioning vestibular system. Vestibular recruitment is a disproportionate increase during the strong stimulation versus the weak stimulation and reflects a lesion within the labyrinth or at the receptor organ. Vestibular decruitment when the weak stimulation period produces a stronger response than the strong stimulation period and indicates intracranial disease.

Simultaneous Binaural Bithermal Caloric Test

Procedure: The procedure as described by Brookler (1975) requires the simultaneous irrigation of each external auditory canal first with the cool (30°C) water for 60 seconds. After the stimulation is completed the recorder is turned on and eye movements are traced for at least 90 seconds. The procedure is then repeated with 44°C water for the same amount of time.

Clinical significance: The SCV is calculated from an average of the best ten seconds of each tracing from a minimum of three nystagmus beats.

There are three possible answers when there is no nystagmus present. First, a normal system will have no nystagmus present because there will be no imbalance between ears. Second, a bilaterally dead system will also have no response because there will not be an imbalance between the labyrinths. And third, a bilateral hyperactive system again, because no imbalance has been created.

Another possible result of this procedure is a response in one direction for a cold stimulation will be in the opposite direction for the warm stimulation. This indicates a peripheral lesion.

A third result of this test would be to have a direction fixed nystagmus, regardless of the temperature of the stimulus. This result is considered to be non-localizing.

Brookler (1975) in a study of 1180 vestibular examinations determined that the procedure should not be utilized as the only caloric test. He found that when the results of this procedure when combined with the results of the bithermal caloric test were 55% more sensitive.

ADDITIONAL INFORMATION UTILIZED IN THE DIAGNOSIS OF THE DIZZY PATIENT

A diagnosis regarding the anatomical site of lesion should not be made on the basis of ENG test results alone (Barber & Stockwell, 1980; Kumar & Sutton, 1984). A compilation of information representing the symptoms, and measured physical manifestations should be obtained through the case history, the audiological test results and, of course, the ENG.

Case History

A case history should include a description of the dizziness by the patient. Is the patient experiencing what is called "true vertigo"? True vertigo exists when the patient actually complains of the room spinning around him and not just a light headed feeling. Information regarding the consistency of the dizziness can be very important. Is the patient constantly dizzy, the same degree of dizziness, or does the dizziness come in attacks? If the patient is experiencing attacks of dizziness, the patient should describe what happens when the dizziness comes on, how fast the spells hit, as well as how he copes with the dizziness.

The patient should be asked if there are any other symptoms that accompany the dizziness, such as, head aches, nausea, and of course, tinnitus. If tinnitus is present either during the dizziness or when the dizziness has subsided, the patient should describe the type of tinnitus he is experiencing (i.e. is it high pitched or a roaring sensation?)

Medications the patient is taking may be causing the dizziness, therefore, it is very important to ask about the use of drugs, regardless, of whether they are for health or recreational purposes. Alcohol can also have an affect on the vestibular system and may contribute to the dizziness.

The case history may be informal and may be done while the electrodes are being placed on the patient in an effort to save time.

Audiological Evaluation

The audiological examination should include an audiogram demonstrating the type, degree and configuration of hearing loss, if any exists. Speech discrimination scores are also valuable information. Acoustic immittance testing to determine the integrity of the middle ear system as well as acoustic reflex thresholds and acoustic reflex decay should also be completed. The information obtained in the audiological evaluation has a localizing value in and of itself, and, when combined with the information from the case history and ENG, allow the physician to form a diagnosis.

Chapter 5

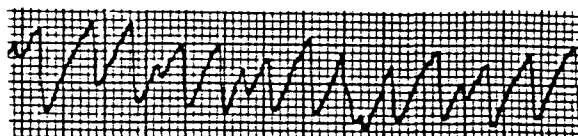
CASE STUDIES

Three case studies have been selected from the files of the Speech and Hearing Clinic of Rush-Presbyterian St. Luke's Medical Center, Chicago, Illinois, to demonstrate the use of ENG in diagnosis. Patients were selected to represent three categories of diagnosis; a normal vestibular system, peripheral vestibular lesion, and a central vestibular lesion. The files were chosen based on the characteristics of the ENG.

Patient "A", a 61 year old female, was seen at the clinic on 3 occasions with a complaint of mild hearing loss and dizziness. She described a constant light headed feeling and stated that the room did not actually spin. The patient also stated that the light headed feeling began approximately one year ago. Results of audiological testing revealed normal hearing sensitivity for the right ear and a mild high frequency sensorineural hearing loss in the left ear. Speech discrimination ability is excellent, bilaterally. Acoustic immittance testing revealed normal tympanograms in both ears and acoustic reflexes were elicited at normal sensation levels. Acoustic reflex decay at 500 and 1000 Hz is negative, bilaterally. The results of the audiogram represent a normally functioning auditory system with the exception of the mild high frequency hearing loss in the left ear.

ENG test results reveal normal calibration. No spontaneous, positional, positioning or gaze nystagmus is present.

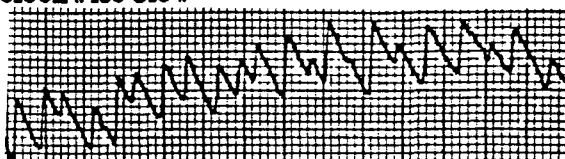
Optokinetic nystagmus is symmetrical and well formed.



Clockwise Slow



Clockwise Fast

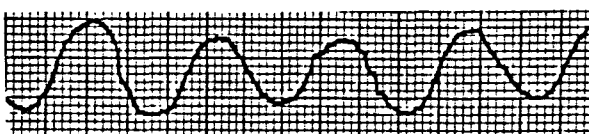


Counter Clockwise Slow

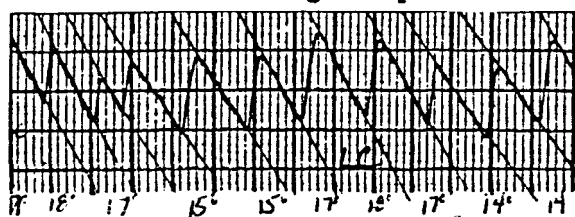


Counter Clockwise Fast

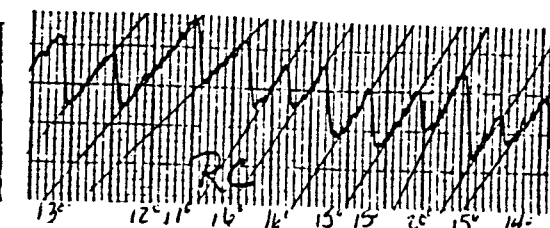
Pendular tracking is within normal limits.



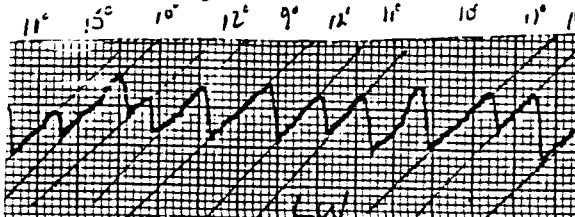
Bithermal binaural caloric testing was performed utilizing cold (24°) and warm (50°) air for a 60 second irrigation period.



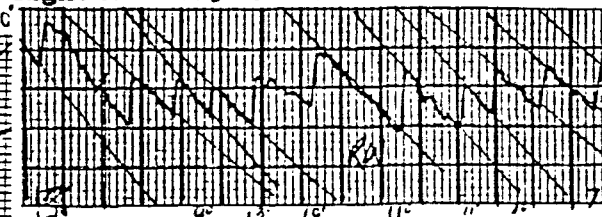
Left cold - $16.25^{\circ}/\text{second}$



Right cold - $14.5^{\circ}/\text{second}$



Left warm - $11^{\circ}/\text{second}$



Right warm - $9.8^{\circ}/\text{second}$

The sensitivity difference as calculated with the formula previously shown in the procedure section is 5.7%. The directional preponderance was calculated utilizing the formula for directional preponderance which was also previously shown and is 1.26%. The sensitivity difference and directional preponderance are not significant.

Impression: The results are consistent with a normally functioning vestibular system.

Patient "B", a 40 year old female, was seen at the clinic with a complaint of dizziness which began approximately six days prior to the testing. The patient stated that the room was constantly spinning and that the severity of the spinning sensation seemed to be less than it was at first. She stated that she had been lifting weights just prior to the onset of the vertigo. The patient also stated she does not drink alcohol and is not on any medications at this time. Audiological test results indicate normal hearing sensitivity, bilaterally. Speech discrimination ability is excellent in both ears. Acoustic immittance testing revealed normal tympanograms, bilaterally. Ipsilateral acoustic reflexes were elicited at normal sensation levels and acoustic reflex decay at 500 and 1000 Hz is negative in both ears. In summary, the audiological test results are indicative of a normally functioning auditory mechanism.

ENG testing revealed a left beating spontaneous nystagmus of $4.25^{\circ}/\text{second}$, which persisted in all test positions.



Spontaneous = $4.24^{\circ}/\text{second}$
(Erect, eyes closed)

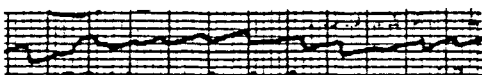
Positional Testing:



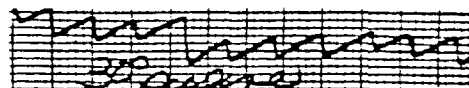
0° supine



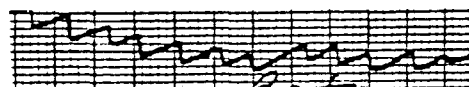
Right lateral



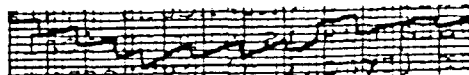
Left lateral



30° supine



Right neck torsion



Left neck torsion

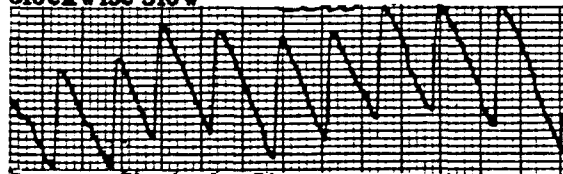
Optokinetic nystagmus is symmetrical and well formed:



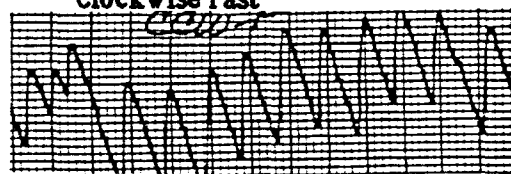
Clockwise Slow



Clockwise Fast

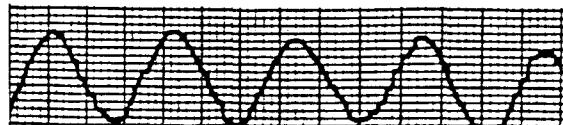


Counter Clockwise Slow

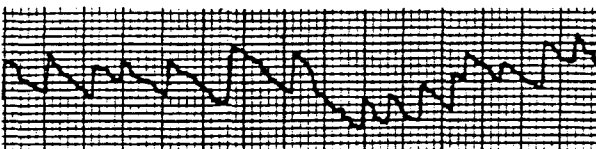


Counter Clockwise Fast

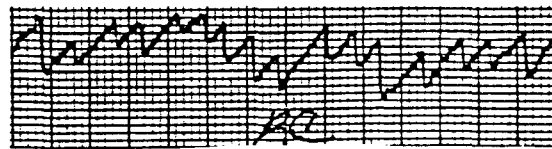
Pendular tracking responses are within normal limits:



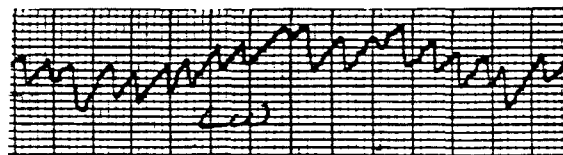
Bithermal binaural caloric testing was performed utilizing cold (24°) and warm (50°) air for a 60 second irrigation period.



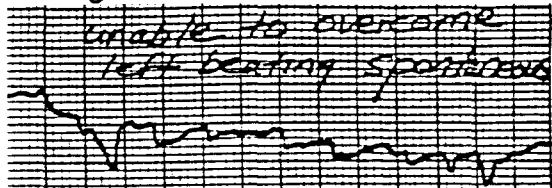
Left cold - 8.8° /second



Right cold - 9.9° /second



Left warm - 10.7° /second



Right warm - 0° /second

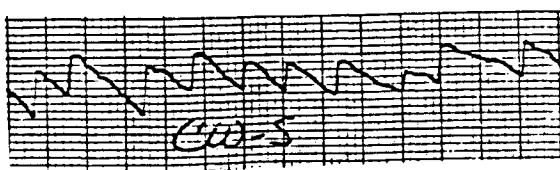
The sensitivity difference is 46%, demonstrating a significant right unilateral weakness for this patient. The directional preponderance is 16% and is not significant. This case demonstrates the need to add and subtract the spontaneous nystagmus into the caloric responses. Patient "B" was unable to overcome the spontaneous nystagmus

when stimulated with warm air to the right ear and therefore presented a perverted left beating nystagmus when the nystagmus should have been right beating. When the spontaneous nystagmus was added to, and subtracted out of the caloric responses, the patient demonstrated no response at all to warm stimulation of the right ear.

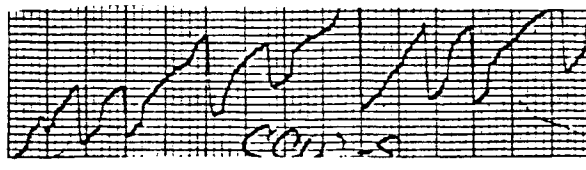
Impression: The patient demonstrates a right unilateral weakness consistent with right peripheral dysfunction.

Patient "C", a 35 year old female, reported experiencing a constant dizziness in which the room was spinning. She stated that the dizziness began approximately 3 months ago and that it seemed to be getting worse. The patient also stated that she frequently experiences head aches accompanied by nausea. Patient reported that she used to drink alcohol occasionally but, since the dizziness began she has not had any desire to drink. The patient demonstrates normal hearing sensitivity with excellent speech discrimination ability in both ears. Acoustic immittance testing revealed normal tympanic membrane mobility, bilaterally. Acoustic reflexes are present at normal sensation levels and acoustic reflex decay at 500 and 1000Hz is negative.

The ENG test results reveal no spontaneous, positional, positioning or gaze nystagmus and normal saccade responses. Optokinetic nystagmus is symmetrical but poorly formed.



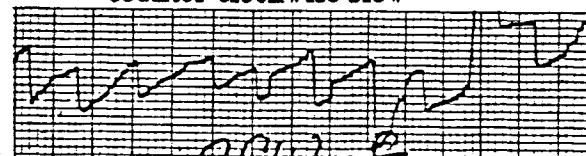
Clockwise Slow



Counter Clockwise Slow

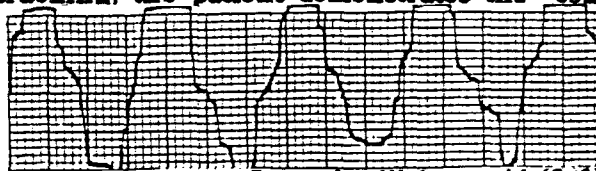


Clockwise Fast

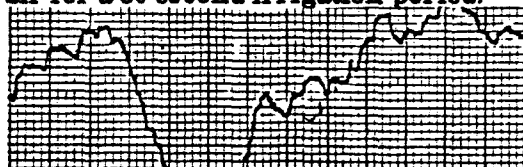


Counter Clockwise Fast

During smooth pursuit tracking, the patient demonstrates the "cogwheeling" effect previously discussed.



Bithermal binaural caloric testing was performed utilizing cold (24°) and warm (50°) air for a 60 second irrigation period.



Left cold = 0° /second



Right cold = 0° /second



Left warm = 0° /second

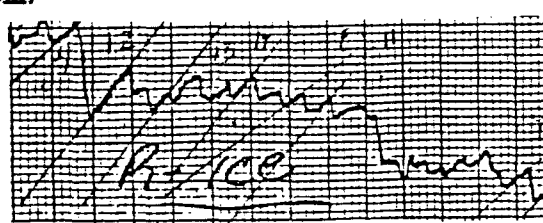


Right warm = 0° /second

When responses to air stimulation were not obtained, 5cc of ice water (0°) were administered to stimulate the vestibular system.

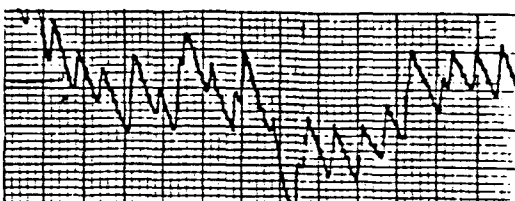


Left Ice Water = 30.5° /second

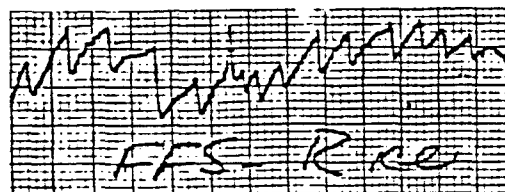


Right Ice Water = 9.7° /second

Although ice water responses reveal some vestibular function, the results indicate a bilateral hypofunction. Fixation suppression was poor as is demonstrated in the following tracings of ice water responses with the eyes open.



Left Ice Water-Eyes Open



Right Ice Water-Eyes Open

Impression: A bilateral weakness is considered to be a nonlocalizing finding. However, the failure of fixation suppression as well as the poor pendular tracking are suggestive of a central abnormality.

The case studies presented represent only a fraction of the combination of ENG results that are possible. The cases stress the importance of evaluating all the responses to form a complete picture of the functioning of the vestibular system.

Chapter 6

SUMMARY AND CONCLUSION

The purpose of this paper is to describe one of the techniques utilized to assess vestibular function; Electronystagmography (ENG). ENG is a method of electrically monitoring eye movements. Specifically, the eye movements that ENG reports to measure are known as, nystagmus. Vestibular nystagmus contains a slow phase and a fast phase. The nystagmus which previously had to be visually observed by the physician can now be detected and analyzed through the use of ENG equipment.

As previously stated, nystagmus can be present spontaneously, be induced by a specific position or, induced by movement into a given position. Nystagmus may also be induced through visual stimuli and/or indirect manipulation of the fluid in the semicircular canals. The characteristics of the nystagmus can be analyzed to aid in the localization of a possible lesion affecting the vestibular system. Table 1 summarizes the information revealed in the "Stimulation Procedure and Clinical Significance" chapter within this paper.

ENG is useful for differentiating peripheral lesions of the vestibular system from those lesions located more centrally. The results obtained through ENG should be combined with audiological results as well as information obtained during the case history and physical examination to provide a physician with a complete picture.

A major criticism of ENG is that, in most instances, the results only differentiate peripheral from central lesions and cannot determine specific anatomical locations of the lesions. When a central lesion can be ruled out based on the ENG test results, the patient is spared the time and expense of a complete neurological work-up. The use of computers is increasing the effectiveness of ENG testing; with a higher level of control over the stimulus and increased sophistication of response analysis, researchers and

clinicians are obtaining increasingly more accurate results in the hopes of determining more specifically, the anatomic site of lesion. It is this authors opinion that the technological advances of the future will increase the usefulness of ENG in the clinic as a diagnostic tool.

Who should administer the test and interpret the results is another controversial issue surrounding ENG. A physician has a choice in this matter, he may hire a technician and buy the necessary equipment or he may have an audiologist do the testing.

There exists a strong case for having the audiologist perform the testing. Audiologists have the most appropriate academic background for understanding the anatomy and physiology of the vestibular system. The physiologic principles in the vestibular system are much like the hearing mechanism. Also, the results obtained during the ENG need to be compared with the audiological results to determine a full picture of the patient's auditory and vestibular systems. When all the test results have been compiled by one examiner, the full picture of the inner ear is likely to be more consistent.

The audiologist who has decided to make ENG testing a portion of his repertoire should avoid stepping into the technician role. By offering only diagnostics of the vestibular system, the audiologist is a mere technician in vestibular testing. The audiologist should be willing to follow through on the testing with counselling and coping strategies in cooperation with the physician, to provide a full range of services for the patient. The physician often does not spend the necessary time counselling the patient on the medications provided or on coping strategies for the dizzy patient. The counselling role should become an integral portion of the ENG expertise that the audiologist has to offer his patients. The audiologist who is willing to learn more about

the functioning of the vestibular system and to explore ways to help patient's cope with the dizziness will be fulfilling his role as an audiologist and will not be a technician.

Table 1

| STIMULUS PROCEDURE | CHARACTERISTICS OF NYSTAGMUS | SITE OF LESION |
|--------------------------|--|---------------------|
| ***** | | |
| Spontaneous Nystagmus | Present in sitting position, inhibited by fixation, rotatory ***** | Peripheral ***** |
| ***** | Not inhibited by fixation, either horizontal or vertical. ***** | Central ***** |
| Positional Nystagmus | Direction-fixed or changing, inhibited with fixation except during the acute stages ***** | Peripheral ***** |
| ***** | Direction-fixed or changing, not inhibited with fixation ***** | Central ***** |
| Positioning Nystagmus | Unidirectional, rotatory, latency brief duration, fatigues ***** | Peripheral ***** |
| Gaze Nystagmus | Present in only one direction, horizontal component only, ***** | Peripheral ***** |
| ***** | Changes direction with a change in gaze ***** | Central ***** |
| Saccades | Dysmetria, Saccade slowing, Overshoot or Undershoot, Normal ***** | Central ***** |
| Tracking, Smooth Pursuit | Choppy lines, step-like formation ***** | Central ***** |
| Optokinetics | Asymmetrical ***** | Central ***** |
| Caloric Stimulation | Significant sensitivity difference, Directional preponderance ***** | Peripheral ***** |
| | Directional preponderance, Dysrhythmia, Impaired fixation suppression, Perverted nystagmus | Central |

The table shown above demonstrates the localizing value of the results obtained with various stimulations. The information presented in the chart summarizes the research presented in the previous pages.

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